This paper has been printed as manuscript in limited quantity for preliminary use. As this reproduction does not constitute formal scientific publication, any reference to the paper in published articles and scientific literature should identify it as a manuscript of the U. S. Weather Bureau Southern Region.

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
U. S. Weather Bureau

Southern Region Technical Memorandum No. 33, March 1967

AN EMPIRICAL METHOD FOR FORECASTING RADIATION TEMPERATURES IN THE LOWER RIO GRANDE VALLEY OF TEXAS

Leroy B. Hagood
WBAS, Brownsville, Texas

TABLE OF CONTENTS

AN EMPIRICAL METHOD FOR FORECASTING RADIATION TEMPERATURES
IN THE LOWER RIO GRANDE VALLEY OF TEXAS

Leroy B. Hagood
WBAS, Brownsville, Texas

INTRODUCTION

The forecasting of minimum temperatures for the benefit of the agricultural interests of the Lower Rio Grande Valley is an important part of the work of the Weather Bureau Office at Brownsville. An empirical method for forecasting minimum temperatures is presented here. Due to winter crops of fruits and vegetables, the forecasts are of most significance during the period November through March.

Potential critical temperature situations over the Lower Rio Grande Valley are usually characterized by a high pressure system centered over central or western Texas with the center moving toward Brownsville or into Mexico a short distance west of Brownsville, or a high pressure area becomes stationary over the southern tip of the state. With a moving high pressure system, the critical period usually lasts only one night. With a stationary high, the low temperature potential may persist for several nights.

Many factors influence the amount of radiational cooling for a given locality. Among these are soil type, ground cover, and state of ground i.e., whether the ground is wet or dry. Certain atmospheric phenomena play an important role in the radiation process. The more important of these are amount and height above the surface of cloud cover, wind, and amount and distribution of water vapor at the surface and aloft. Even with conditions seemingly quite similar, on numerous occasions significant differences in the amount of radiational cooling have been observed at Brownsville. An examination of several radiation situations revealed that one factor showing a significant variation was the velocity of the winds aloft, especially to five thousand feet. This indicates that turbulent mixing of the air limits the amount of radiational cooling in proportion to the wind velocities from the surface through five thousand feet. This is the basis for the formulas to be discussed below.

BASIC FORECAST ASSUMPTIONS

In attempting to develop an empirical method for forecasting minimum temperatures for the Lower Rio Grande Valley under maximum radiation conditions, it was considered desirable to make certain basic assumptions. It seemed reasonable to suppose that there is a limit to the amount of radiational cooling observed during any given night with maximum radiation conditions.

We may assume that skies will be clear during the night or at least during the four or five hours immediately preceding sunrise. Pressure will be relatively high with the barometer usually having a steady or rising tendency. It is believed that ground cover, such as citrus groves, agricultural plantings, brush, and pasture lands will be much the same during the November through March period from year to year. The foregoing factors, together with soil type, may be grouped together, and their effect on radiational cooling will be indicated by some constant of maximum radiation cooling under ideal conditions. This leaves the variables of water vapor and wind to be considered.

MAXIMUM RADIATION CONDITIONS

To determine a value for the maximum cooling factor, consider "ideal radiation conditions". With such conditions, dew point temperatures may be expected to decrease rapidly with height, and are likely to be quite low. Winds will be calm or near calm at the surface and aloft through five to ten thousand feet. With these conditions, in addition to the "constant" factors previously mentioned, the maximum cooling factor for a specific location with maximum radiation conditions may be taken as the greatest difference ever noted between the maximum temperature and the minimum temperature observed during the following night, when the minimum temperature was the result of radiational cooling. For Brownsville, this has been determined to be 30 degrees.

For maximum radiation situations at Brownsville, certain arbitrary limits have been set for winds at the surface and aloft, and dew point temperatures at the surface. These are: (1) the average velocity of the night time surface winds will be less than 10 knots. (2) the average velocity of the winds aloft from one to five thousand feet must be less than 20 knots, and (3) the dew point temperature at the surface will be lower than the computed value for the minimum temperature forecast to occur during the coming night.

FORECASTS UNDER MAXIMUM RADIATION CONDITIONS

Based on the assumption that the maximum amount of radiational cooling, with ideal radiation conditions, will be reduced by an amount proportional to the mean velocity of the surface wind and the winds aloft to five thousand feet, the following equation has been set up for forecasting minimum temperatures at Brownsville:

$$Tmn_1 = Tmx - Mc + Mc\left[\tfrac{1}{2}(\overline{V}+\overline{v})/100\right] \qquad (1)$$

Where Mc = The maximum cooling factor with ideal radiation conditions, (For Brownsville 30 degrees)

Tmn_1 = Forecast minimum temperature

Tmx = Maximum temperature during the afternoon of the current day

$\overline{V}$ = The average wind velocity from one to five thousand feet

$\overline{v}$ = Average surface wind velocity expected during the coming night

All temperatures are in $^{\circ}F$, and wind velocities in knots. Performing the indicated operations and using Mc = 30, the equation becomes:

$$Tmn_1 = Tmx - 30 = 0.15\ (\overline{V} + \overline{v})$$

Example: Data for February 5, 1963

Maximum temperature	-	71°
Effective dew point temperature	-	40°
Average night surface wind	-	calm
Average winds aloft to five thousand feet	-	5kts

Inserting these values in Eq. (1)

$$Tmn_1 = 71^{\circ} - 30^{\circ} + 0.15\ (5+0)$$

$$= 41^{\circ} + 0.75^{\circ}$$

$$= 42^{\circ} \text{(rounding off to the nearest degree)}$$

The observed minimum temperature February 6, 1963 was 42°.

FORECASTS UNDER MODIFIED CONDITIONS

Thus far, only maximum radiation conditions have been considered. There is a type of situation that occurs more frequently, where one or more of the variable factors for maximum radiation have values falling outside the specified limits. These may be termed "modified radiation" cases. This is because the minimum temperature is primarily the result of radiational cooling although the degree of cooling is more noticeably affected. Winds aloft may be stronger, exceeding 20 knots, or night surface winds averaging 10 knots or higher.

Higher velocities at the surface and aloft result in more turbulent mixing of the air, and in so doing, are believed to be a dominant factor in limiting the amount of radiational cooling. The basic equation, (1) is modified to show the correction for higher average values of wind velocities.

$$Tmn_2 = Tmx - Mc + Mc\ \left[(\overline{V} + \overline{V})\ /\ 100\right] \tag{2}$$

and with Mc = 30° simplifies to give the forecast minimum temperature:

$$Tmn_2 = Tmx - 30 + 0.3\ (\overline{V} + \overline{v})$$

Example: November 29, 1960

Maximum temperature	-	63°
Dew point temperature	-	38°
Average winds aloft	-	28 kts
Average night surface wind	-	10 kts

Inserting these values in Eq. (2).

$$Tmn = 63^{\circ} - 30^{\circ} + 0.3\ (28 + 10)$$

$$= 33^{\circ} + 11.40$$

$$= 44^{\circ} \text{ (rounding off to the nearest whole degree)}$$

The minimum temperature recorded the morning of November 30, 1960 was 44°.

CORRECTION FOR INDICATED COOLING BELOW THE DEW POINT

Frequently the minimum temperature computed using equations (1) or (2) will be lower than any dew point temperature, td, expected during the forecast period. In these cases, using Eq. (1) or (2) depending upon the wind factor, a value for Tmn is computed. To introduce the effect of the higher dew point a third equation is used. This is in the form:

$$Tmn_3 = Tmn + (td-Tmn)-(td-Tmn)(\overline{V}/100)$$

Factoring, $$Tmn_3 = Tmn + (td-Tmn)(1-\overline{V}/100)$$

This is to indicate that the value for Tmn, computed from Eq. (1) or (2), will be increased by an amount equal to the product of the difference between the higher dew point and the computed minimum, and a percentage value derived from the average winds aloft.

Example: January 15, 1964

Maximum temperature	-	61°
Dew point temperature	-	42°
Average winds aloft	-	14 kts
Average night surface wind	-	6 kts

From Eq. (1) $$Tmn_1 = 61^\circ - 30^\circ + 0.15\ (14 + 6)$$
$$= 31^\circ + 3^\circ$$
$$= 34^\circ$$

Inserting the value for Tmn in Eq. (3)

$$Tmn_3 = 34^\circ + (42\text{-}34)(0.86)$$
$$= 34^\circ + 7$$
$$= 41^\circ$$

The observed minimum temperature January 16, 1964 was 42°.

VALIDITY OF THE EQUATIONS

To verify the procedures, 25 days, when the minimum temperatures were considered to have resulted from radiational cooling, were selected between the dates of November 30, 1957 and January 4, 1964. For the 25 days the average error was 1.20 degrees. An examination of the periods November 1964 through March 1965, and November 1965 through March 1966 gave an additional 50 days meeting the criteria for applying the formulas. For the total of 75 forecast days the average error was 1.49 degrees. There were 25 days with wind alone limiting radiational cooling. For the 25 days the average forecast error was 0.96 degrees. Either equation (1) or (2) was used in combination with Equation (3) 50 times with an average error of 1.78 degrees.

TABULATING ACCORDING TO THE OBSERVED MINIMUM TEMPERATURE:

Observed Minimum Temperature	Number Forecast Days	Average Forecast Error
60 - 69	10	1.80
50 - 59	18	1.89
40 - 49	31	1.51
30 - 39	15	0.80
20 - 29	1	1.00

OBTAINING FORECAST PARAMETERS

The empirical formulas presented here are not meant to, and in fact cannot, take the place of forecasting ability. The formulas are only a forecasting aid. The ability to anticipate significant changes, particularly in winds and dew point temperatures, may be the deciding factor in the final accuracy of the formulas.

The formulas were designed to be used as early in the forecast day as synoptic conditions will permit. If, as is frequently the case, there are no expected significant changes in the air mass, or in the wind field aloft, the afternoon forecast will utilize observed data. The value for $\overline{V}$ is taken from the 18Z pibal of the current day, and the 18Z dew point at the surface is used for td. With the maximum temperature for the day reached prior to the time of the forecast, the only element necessary to forecast is the average velocity of the surface winds during the coming night. If a significant change in either surface dew point temperature or winds aloft is indicated, then the forecast values for those factors will be used in the computations.

APPLICATION IN FORECASTING

The simplicity of application is a factor in favor of the methods. There is no extensive time consuming collection of data required. The formulas have been applied to forecasting minimum temperatures for the Rio Grande City area with satisfactory results, using a value of 42 degrees for the maximum cooling factor, Mc. Thus, the empirical methods presented here for forecasting minimum temperatures have proven to be an effective tool not only for the Brownsville areas but for the entire Lower Rio Grande Valley.